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Will the Clean Development Mechanism Mobilize Anticipated Levels of Mitigation?

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Abstract

Under the Kyoto Protocol, developed countries can only tap mitigation opportunities in developing countries by investing in projects under the Clean Development Mechanism. Yet Clean Development Mechanism investments have so far failed to reach many of the high-potential sectors identified by the Intergovernmental Panel on Climate Change. This raises doubts about whether the Clean Development Mechanism can generate an adequate supply of credits from the limited areas where it has proved successful. This paper examines the current trajectory of mitigation projects entering the Clean Development Mechanism pipeline and projects it forward under the assumption that the diffusion of the Clean Development Mechanism will follow a path similar to other innovations. Projections are then compared with pre-Clean Development Mechanism predictions of the mechanism's potential market size to discern whether limits on the types of projects entering the pipeline have limited the expected supply of certified emission reductions. Parameter tests suggest that this is not the case and that currently identified Clean Development Mechanism investments will generate offsets in excess of early model predictions. In particular, under favorable circumstances, the mechanism is on track to deliver an average annual flow of roughly 700 million certified emission reductions by the close of 2012 and nearly to 1,100 million certified emission reductions by 2020.

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Introduction

The Kyoto Protocol, the convention that regulates the climate change combating activities agreed upon by the international community, has two project-based investment mechanisms that are designed to encourage low-carbon growth and to help industrialized countries reduce the cost of meeting their emission reduction targets in the first commitment period, which runs from 2008 to 2012. The first program, Joint Implementation (JI), allows these countries to claim credit for emission reductions that arise from new low-carbon investments in other industrialized countries. The second program, the Clean Development Mechanism (CDM), allows emission-reduction projects in developing countries that generate "certified emission reductions" (CERs) for use by the investor country and foster sustainable development in the host country. Under both programs, participants include both the public and private sector. However, in terms of the scale of current investments under the program and in terms of its mitigation potential, the CDM is by far the larger of the two.[2]

Under the Kyoto Protocol, the CDM is the only formal way for the industrialized Annex B countries that have pledged to reduce greenhouse gas emissions to tap potential sources of mitigation in countries that have not pledged reductions[3]. For the most part, developing countries comprise the second group and are known, in Protocol parlance, as non-Annex B countries.

In most instances, a CDM project is a direct investment by an Annex B government or firm hosted by a non-Annex B country.[4] Projects are designed with the objective of reducing greenhouse gas emissions or speeding the removal of greenhouse gases from the atmosphere relative to a business-as-usual baseline, and must be approved by the governments of both investor and host.[5] In addition, they are reviewed individually by a CDM Board prior to implementation and are subject to continuous monitoring and a verification process. If successful, the projects generate offsets (CERs) that Annex B countries can use to meet their Kyoto obligations. Overall, the CDM is expected to lower

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[2] Offsets from JI projects are called Emission Reduction Units (ERUs). Both ERUs and CERs are tradable. Another source of flexibility in the Protocol is a provision that allows Annex B countries (named for the UNFCCC annex that lists them) to trade assigned amount units (AAUs), national units that correspond to emission levels permitted under pledged caps.

[3] Annex B countries are named for the section of the Kyoto Protocol in which they are listed. Currently 38 countries including the European Community are listed in Annex B.

[4] In some “unilateral” projects, the eventual credit buyer is determined late in the project cycle.

[5] For a discussion of pilot programs preceding the CDM, see Larson and Breustedt (2009)

the cost of meeting the environmental goals of the Kyoto Protocol by encouraging investments in low-cost abatement efforts wherever they can be found. Another stated objective of the CDM is to help host developing countries achieve sustainable development through the mobilization of direct private foreign investment and technology transfer.[6]

With its dual objectives, the CDM attracts both Annex B and non-Annex B parties to the convention. Since its inception in 2003, Greenhouse Gases (GHG) abatement activity under the CDM has increased rapidly. According to The UNEP Risoe Centre on Energy, Climate and Sustainable Development, a total of 5,316 CDM projects had been submitted to the CDM Board for validation by August 2009 (UNEP Riscoe, 2009). Of these 1,792 of the projects had been validated and registered by the CDM board; 234 were in the process of registration; 2,605 were in the process of validation; and 685 projects were either withdrawn or rejected. Together, the 4,631 projects in the August 2009 pipeline are expected to generate approximately 2.79 billion CERs during 2008-2012, the first commitment period of the Kyoto Protocol. Moreover, many investors expect the CDM or some similar mechanism to continue beyond the first commitment period and many CDM projects currently underway will generate emission reductions well beyond 2012.

Nevertheless, the scope for additional CDM projects is limited by the fundamental components of demand and supply, which are, in turn, determined by the rate and composition of global economic growth, current Kyoto targets, expectations about future regulations, as well as domestic and JI mitigation efforts in Annex B countries.

Another line of analysis could be to examine the determinants (including time and country-specific attributes) that explain differences in the probability and level of CDM adoption over time and across countries, with distinction between developing (host) and developed (investor) countries. The adoption and diffusion functions complement each other in that individual-level explanation is provided in the adoption analysis and an economy-wide explanation is provided in the diffusion analysis, which further help to analyze policy interventions that may affect the trend of CDM adoption.

As is discussed later, there are a variety of predictions about the size of the eventual CDM market that take these fundamentals into account. In this paper, we look at CDM as a new technology that diffuses over time across adopters. We verify whether or not our

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[6] A detailed description of the CDM and analysis of the issues related to this provision can be found in Larson et al. (2008) and Lecocq and Ambrosi (2007).

predictions of CDM diffusion are consistent with the historic pattern of growth in CDM projects and behave according to conceptual models of technology diffusion. We fit a sigmoid expansion path model to historic CDM expansion data and test whether the predicted size of the CDM market will be exceeded during the first commitment period of the Kyoto Protocol and beyond. Estimates of the future size of the CDM market are of paramount importance to investors and policy makers as both groups are concerned with the attractiveness of the CDM mechanism. One of the questions discussed in the UNFCCC Conference of the Parties (COP) in Copenhagen in December 2009 is whether or not CDM should remain one of the major mechanisms to allow countries reduce the cost of meeting their emission reduction targets. The answer to such question may rely heavily on the trends of the CDM market, as predicted in our analysis.

The remainder of the paper is organized as follows. The next section presents a brief review of relevant literature on diffusion of technologies. Section three examines the mitigation potential of the CDM and presents the available estimates of the size of the CDM market. Section four describes the CDM pipeline data and presents the empirical results for the CDM diffusion pattern along with projections of CDM activity during and beyond the first commitment period of the Kyoto Protocol. The last section discusses the policy implications, indicates areas of future research, and concludes.

Technology Diffusion Literature

Various models of diffusion have been developed to explain changing populations, technology diffusion, and adoption of new consumer products. All of those models are founded on theories concerning the spread of information either through interactions between adopters and non-adopters or through exogenous sources (Feder and Umali, 1993). Aggregate models on technology diffusion are founded upon the epidemic or logistic model[7]. The logistic model views the diffusion process to be similar to the spread of an infectious disease, with the analogy that contact with other adopters (i.e., learning from the experience of others) and exposure to information on the innovation (i.e., demonstration effect) leads to adoption. The model is based on the assumption that members of a

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[7] See, for example, Griliches (1957, 1980), Mansfield (1961), Gore and Lavaraj (1987), Doessel and Strong(1991), Knudson (1991) and Danar and Yaron (1992).

homogeneous population have an equal probability of coming into contact with each other and that the flow of new adopters of the technology in a given point in time is a function of the stock of existing adopters. When the stock of existing adopters is small, there is little risk of "contagion." The risk of "contagion" increases as the stock of existing adopters increases (potential adopters decreases), and the flow of new adopters rises exponentially. However, as the stock comes closer to the total number of potential adopters, the flow of new adopters gradually decreases and eventually becomes zero. The diffusion of the innovation thus follows a symmetric S-shaped function over time. Since adoption is a cyclical process, new technologies would replace existing ones and thus a process of technology abandonment would take place as well.

The symmetry of the logistic model, however, does not always fit observed patterns. To account for asymmetric growth patterns, a family of exponential growth models has been developed and used (Gregg and Hassell, 1964). The exponential growth models include the Gompertz, the flexible logistic, the log-normal, and the cumulative log-normal models. The Gompertz model imposes an asymmetric S-shape on the growth curve and attains its point of inflection when diffusion has reached approximately 37% of the upper bound (Dixon, 1980; Michalakelis, Varoutas and Sphicopoulos, 2008). While the logistic and Gompertz models have fixed inflection points, the point of inflection and degree of symmetry of the flexible logistic model are also determined by the data (Bewley and Fiebig, 1988). The log-normal distribution may be more appropriate in some economic applications since many economic variables cannot have negative values and do not have symmetric distributions as the normal distribution has (Madala, 1977). The inflection point is variable in the cumulative log-normal model. Thus, the model can generate a whole family of asymmetric S-shaped curves. However, instead of a single diffusion curve, there may exist an envelope of successive diffusion curves, each associated with a given set of innovations and environmental characteristics, adoption ceiling, and rate of adoption (Metcalfe, 1981).

Not only internal sources of information (i.e., learning from the adopters) but external sources of information (e.g., the mass media) may also shape the diffusion process (Lekvall, and Wahlbin, 1973). Moreover, heterogeneity of the population may also affect the diffusion process (Coleman, 1964; Davies, 1979). Taking account of dual (endogenous and exogenous) sources of information and population heterogeneity, a new product growth model is developed (Mahajan and Schoeman, 1977). The model categorizes the population in two groups: the innovators, who adopt the new technology or product based on exogenous information, and the imitators, who adopt based on endogenous information (learning from the adopters).

While empirical studies show that different diffusion models fit different situations effectively, this paper employs both logistic and Gompertz models to examine the aggregate diffusion of the CDM. In the case of CDM, the analogy to the epidemic model is that exposure to the opportunity and learning from the experience of the countries that have already adopted the mechanism lead new countries to adopt the mechanism. Also, the ability of investor countries to invest in several host countries leads to increased learning and adoption.

Mitigation Potential, Model Predictions and the CDM Pipeline

Drawing on a combination of top-down and bottom-up studies, the IPCCC [24] concluded that most of the economic potential for emission reduction is in developing countries (table 1). Studies reviewed by the Panel suggest that upwards to 3.3 gigatons of that potential represents possible win-win improvements in efficiency that would pay for themselves in the long run. However, even at a low carbon prices of less than $US 20 per ton of CO_2 equivalent (tCO_2e), a consensus view is that roughly half of a global mitigation potential of 7.4 $gtCO_2e$ can only be brought into the Kyoto trading system via the Clean Development Mechanism. Moreover, as prices increase developing countries' share of global mitigation potential increases.

At the same time, recent experience suggests the CDM project cycle is better suited to some types of mitigation projects than others. Because developing countries have not pledged emission reductions, CDM projects rely on counter-factual business-as-usual scenarios, or baselines, to calculate the number of offsets that enter the Kyoto trading system. The methodology for determining the project baseline and the plan for monitoring project outcomes is reviewed by the CDM Executive Board case-by-case and each project must be approved before it can go forward. Outcomes from the project are reviewed as well prior to the issuance of CERs. The approach is intentionally conservative and came about because of conceptual uncertainties about how to construct baselines and a deep suspicion by some treaty negotiators that project monitoring would be weak unless closely watched, which would in turn result in watered-down credits with limited environmental benefits [1, 3].

Table 2 lists the number and mitigation potential of projects in the CDM pipeline – that is, projects that are at some stage in the formal CDM project cycle. A quick comparison with the previous table reveals that the distribution of pipeline projects differs from the distribution of project types that the potential-mitigation studies predict. The data in the table is from September 1, 2009 and to that point in time, most of the mitigation potential in identified projects stemmed from hydro-electric power generation, from improvements in manufacturing processes that lowered emissions of heavy greenhouse gas emissions like those associated with hydrofluorocarbons, from land-fills and from improvements in "own generation" energy projects in which electricity is recovered or produced from waste gas.[8] In contrast, despite large potential, few projects having to do with forests or soils are in the pipeline. This is because procedures for constructing baselines and monitoring outcomes for land projects are especially complex under current CDM rules and because the projects face additional restriction on how the CERs that they produced are used [2, 25, 26]. Similarly, few projects that have to do with improving the efficiency of new or existing buildings are in the pipeline, in part because of issues of scale and prohibitions on sector-wide baselines.

All of this suggests that project developers have drawn on a sub-set of identified economically viable mitigation sources, presumably because of constraints and incentives provided by current CDM rules. In contrast, model predictions of the eventual flow of CERs predicted by well-known models are not similarly constrained and are built up from the type of abatement cost curves that underlie the IPCCC reports. An important implication then is that the volume of CERs produced during the Kyoto Protocols first accounting period may fall short of the volumes anticipated by economic models. This, in turn, implies that developed countries would find it more difficult to meet reduction targets pledged in Kyoto and that the cost of the treaty would be greater than anticipated.

With this as background, table 3 summarizes early model predictions of the Annex B countries' potential demand for total emission reductions and the potential size of the CDM

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[8] This last class of projects is most often associated with iron, steel and cement production.

markets.[9] These estimates, which were known and discussed as the CDM program began, range from 0 to 520 million tCO_2e per year by 2010. When looking at the range of values, it is important to keep in mind that the low-end predictions were based on scenarios in which large volumes of "hot air" AAUs, mostly from Russia and the Ukraine entered carbon markets, crowding out offset projects. To date, this scenario has not played out and current outcomes are more consistent with scenarios associated with the high-end estimates (Larson et al., 2008).

Is the CDM on Track?

In this section we look at the expansion path taken so far by the spreading network of CDM projects and markets in order to judge whether the CDM is on track to meet early expectations, based on the diffusion trajectory taken by new methods and technologies in the past. As prelude, we briefly discuss the construction of the data and the specification of the applied models used to fit the data.

Data description

As discussed, projects that potentially generate Certified Emission Reduction credits must be approved by the CDM Executive Board (EB) in advance. Project sponsors must show that their method for calculating baselines is consistent with a methodology that has been previously approved or seek approval for the method that they propose. They must also lay out a monitoring and verification procedure and identify a third-party accredited by the CDM Board to implement that process. All of this is described in a standard format known as the Project Design Document (PDD). A project visibly enters the CDM project cycle when the PDD is put up for public comments. The PDD also contains an estimated volume of CERs that the project is expected to produce over its life as well as a time-schedule of when project managers expect to ask the EB to issue offsets from the project. UNEP/Risoe begins tracking a project when it is put up for public comment and also records the CERs that are expected to be produced by 2012, the end of the first Kyoto accounting period, and also by 2020 and we use these variables in our analysis.

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[9] Article 6.1.d of the Kyoto Protocol prevent industrialized countries from making unlimited use of CDM by the provision that use of CDM be 'supplemental' to domestic actions to reduce emissions. Thus, the estimates of potential demand for CERs are less than the estimates of potential demand for all Kyoto units.

Summary statistics for the sample are given in table 4. The first projects entered the pipeline in December, 2003 and the sample period ends in our analysis in August 2009, so the first and last rows of the table represent results from partial years. The table gives the number of projects entering the pipeline each year, the additional CERs the new projects are expected to provide annually by 2012 and by 2020, and the accumulated stock of annual project CERs for both periods.[10] A quick examination of the table reveals that the expected flow of CERs from the pipeline corresponds to the high end of early predictions of market size reported in table 3. The table also shows that the number of projects has grown each year, although the rate of growth stalled slightly in 2008. Not all projects that enter the pipeline are successful; some projects are withdrawn by the project developer or rejected by the Board. The last column of the table indicates that about 3-14 percent of the 2012 CERs entering the pipeline are withdrawn or rejected. Averaging masks some of the variation in the scale and frequency with which CERs entered the pipeline. Figure 1 shows the build-up of the introduction of new projects and the stock of CERs against a daily scale.

Applied diffusions models

As discussed, the purpose of this paper is to estimate the CDM diffusion patterns and compare ex ante estimates of CDM market size with predictions from the diffusion models. In particular, we use information about projects entering the CDM pipeline and combine it with an assumption that the adoption of CDM project methodologies follows a path typical of new technologies. We consider two types of models, a symmetric and an asymmetric model.

Following Feder and Umali (1993), the general form of the logistic model for CDM adoption is

$$\frac{dc_t}{dt} = \beta \frac{c_t}{c^*}(c^* - c_t) \, , \tag{1}$$

where, in our case, c_t denotes the accumulated expected flow of amount of CO_2 to be abated through existing CDM pipeline projects at time t, and where c^* denotes the overall saturation point, and where β is a parameter measuring the rate of adoption. With time, the

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[10] The UNEP/Risoe data reports total CERs by 2012 and 2020. Annual values are simply these total divided by 5 and 10 respectively. This is done to correspond to model projects, which, by convention, are stated as CERs produced annually.

spread of CDM markets is expected to slow and reach a steady-state equilibrium. This results in a sigmoid cumulative density function over time. The logistic model thus imposes a symmetric S-shaped adoption trend.

Solving the logistic differential equation (1) for c_t yields the standard logistic growth function

$$c_t = \frac{m}{(1 + \exp[(-b_0 - b_1(t - t_0)]}, \tag{2}$$

where c_t is the annual flow of CERs implied by the projects that have accumulated in the CDM pipeline from the first project in t_0 to time t. There are three parameters that determine the shape of the function: b_0 is the coefficient of integration, which shifts the location (intercept) of the function without affecting its shape; b_1 is a coefficient representing the rate of adoption over time; and *m*, which is an estimate of the saturation point, c^*. Conveniently, these parameters can be directly estimated from a time-series of accumulated CERs implied by the pipeline projects using a non-linear estimator. Moreover, tests of the reasonableness of previous forecasts about the eventual size of the CDM market can be tested by imposing those values on the saturation parameter, *m*.

While the parameters of the functional form given in equation 2 are easy to interpret and the form itself is convenient for estimation, a defining feature of the specification is that the underlying cumulative distribution is symmetric and implies that the maximum adoption rate occurs at a point half-way between zero and the saturation level. This imposes an arbitrary inflection point on the trajectory, which, in turn, has encouraged researchers to use more flexible forms.[11] Among these, one of the more flexible specifications is the four-parameter Gompertz function, which we estimate as an alternative. The form traces out an asymmetric sigmoid shape and is written out as:

$$c_t = b_0 + me^{-b_1 e^{-b_2(t-t_0)}} \tag{3}$$

where, as before, b_0 shifts the location of the function without affecting its shape, *m* is an estimate of the saturation point and where b_1 and b_2 together determine the adoption rate.

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[11] See Michalakelis, Varoutas and Sphicopoulos (2008) for a detailed discussion of alternative applied diffusion models.

Estimation results

Both models were fitted using nonlinear least squares procedures and the results are given in table 5. The standard errors were adjusted by taking into account the number of projects associated with the flow of new CERs.[12] Both forms fit the data well and the R^2 statistic exceeded 0.98 in all cases. The estimated parameters are significant at standard levels. As a check, we also estimated a three-parameter version of the Gompertz function in which the intercept term, b_0, is suppressed; however, the hypothesis that the simpler model explained the data as well as the four-parameter model was rejected.[13]

Keeping in mind that the predictions given in table 3 for the CDM marked ranged from zero to 575 by 2010, with the size of the market for all traded Kyoto instruments ranged from 600 to about 1,734 million CERs annually for 2010, the estimation results suggest that CDM is likely to exceed ex ante expectations, even if the flow of new projects into the CDM pipeline slows as the diffusion model would predict. As summarized in table 6, the saturation parameter, *m*, from the symmetric model suggests a steady-state flow of about 575 million CERs annually by the close of the first period in 2012 and 799 million CERs by 2020 -- the end-date of the projection period for current CDM projects. The related parameter from the more flexible asymmetric model suggests slightly higher steady-state levels of 695 and 1,078 annual million CERs for 2012 and 2020, respectively. Calculated and projected annual flows are given in figures 2 and 3. In both cases, the predicted net gains in the annual production of CERs begin to ebb by 2012.

As might be expected, the more flexible four-parameter asymmetric model provides a better fit. Two tests that compare the two functional forms are presented in the middle section of table 6. The first is a Wald test inferring that the lower-valued saturation parameter the symmetric model is statistically indistinguishable from the saturation parameter from the asymmetric model. The second is a likelihood ratio test inferring that the three-parameter model is not nested in the four-parameter model. In both instances, the results favor the four-parameter asymmetric functional form.[14]

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[12] The practical consequence of this adjustment is to inflate the standard errors, which works against our conclusion that the estimated parameters are statistically significant.

[13] The associated LR test-statistic is distributed $\chi^2(1)=19.21$ and is significant at a one percent confidence level.

[14] Note that the Wald tests reported in table 6 are based on standard errors that are adjusted for the number of projects passed by the CDM Board on a given date. This results in 24 clusters and, consequently, reduces the degrees of freedom in the F-statistic to 24, even though the underlying model is based on 1,131 observations.

As discussed, recent pipeline data already indicates that expected CER flows from pipeline projects exceed ex ante model predictions. From model parameters, it is possible to construct confidence intervals around each observation. Using this approach, we calculated the probability that the cumulative number of CERs identified in August 2009 already exceed the upper limit of 520 million tons of carbon dioxide equivalent (mtCO_2e) predicted by the ex ante model. Based on parameters from the symmetric model, there is a 90 percent probability that the cumulative level of CERs in the August pipeline top the upper range of the model predictions for 2010. Using the better-fitting asymmetric model parameters, the probability exceeds 99 percent. Similarly, a test that the upper bound is really the 520 mtCO_2e is rejected in both models.[15]

It is likely that not all projects in the pipeline will succeed in producing the full complement of credits predicted in documents submitted to the CDM Board and some of the credits may arrive after the close of the first commitment period. Moreover, there remains some skepticism in the environmental community about whether leakage and inexactness in project baselines dilute the environmental integrity of the mitigation effects measured by the CDM. Even so, barring a significant departure from current trajectories, the CDM appears on track to match or exceed early expectations when the program was begun.

Summary and Conclusion

There is a consensus view that, at reasonable prices for carbon, most of the global opportunities for mitigation reside in developing countries. And, to date, the Clean Development Mechanism is the only formal way developed countries can access mitigation opportunities in developing countries to meet their commitments under the Kyoto Protocol. Additionally, recent estimates by the IPCC suggest that a significant portion of the mitigation opportunities in developing countries are in agriculture, forestry and improving building efficiency. Yet, so far, project investments under the CDM are narrowly focused on the energy and industrial sectors, leaving these broad areas of potential untouched. This differs from earlier assumptions of how the program would work and raises the question of whether mitigation opportunities that the CDM currently taps will be sufficient to meet

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[15] The test is based on setting *m* in (2) and (3) equal to 520.

global demand. It also raises the related question of whether constraints stemming from the design of the CDM will drive up the cost of meeting Kyoto's environmental goals.

With this as motivation, we look at the current trajectory of potential mitigation entering the CDM pipeline and project it forward under the assumption that the diffusion of CDM markets will follow a path similar to other kinds of innovation. We then compare those projections to pre-CDM predictions of the mechanism's potential market size used to assess Kyoto's cost, in order to discern whether limits on the types of project entering the CDM project cycle will also limit the eventual supply of CERs. Somewhat surprisingly, we find that it does not. Instead, we find that the current size of the CDM market exceed ex ante model predictions and that the mechanism is on track to deliver an average annual flow of roughly 700 million CERs by 2012. Uncertainties abound concerning how well existing projects will perform; however, it is important to note that the projected scale of the CDM market exceeds the most optimistic early model predictions by roughly 30 percent.

From a policy perspective, the results suggest that the CDM has been, in one sense, extremely successful in achieving significant levels of mitigation by motivating private capital flows. However, the skewed sector composition of CDM projects also suggests that the CDM alone may not be up to the task of fully exploiting known and economically viable sources of mitigation. This suggests great scope for finding additional ways of investing in the mitigation potential of developing countries.

Looking ahead, while the aggregate diffusion functions we estimate provide an important tool to evaluate global CDM trends, it is important that additional research identifies the determinants of differences in cross-country CDM adoption over time and also differences among sectors. Because incentives may differ among participants, there is a need to better understand the underlying determinants for both host and investor countries as well as the reasons why some countries pursue unilateral investment strategies.

Table 1. Estimated Economic Potential for Mitigation in 2030 under Alternative Price Scenarios, Giga tons of carbon dioxide equivalent ($GtCO_2e$)

Mitigation Sources	Low prices	High prices
Global	15.80	31.10
OECD countries	4.90	7.40
Transition economies	1.80	2.80
Developing countries	8.30	16.80
Developing country sector		
Energy supply	1.30	2.70
Transport	0.15	0.15
Buildings	2.70	3.30
Industry	1.60	3.80
Agriculture	1.60	4.50
Forestry	0.75	3.00
Waste	0.20	0.70

Source: Table 11.3 in chapter 11 of IPCC Working Group III [24]

Table 2. CDM Pipeline Inventory of Projects, by Project Type

	Number of Projects	Annual CERs 2008-2012	Annual CERs 2008-2020
	4,631	2,786,791	7,416,430
Project type		Share of Total (%)	
Afforestation	0.11	0.01	0.18
Agriculture	0.02	0.01	0.01
Biomass energy	14.29	7.02	6.49
Cement	0.63	1.13	0.79
CO2 capture	0.06	0.01	0.01
Coal bed/mine methane	1.45	4.62	4.71
EE households	0.45	0.14	0.14
EE industry	3.13	0.78	0.61
EE own generation	9.78	9.27	8.68
EE service	0.37	0.03	0.03
EE supply side	1.32	1.39	2.70
Energy distribution	0.19	0.35	0.34
Fossil fuel switch	2.33	6.37	6.13
Fugitive gas	0.50	1.92	1.66
Geothermal	0.32	0.60	0.58
HFCs	0.48	17.10	14.83
Hydro	26.97	17.23	20.75
Landfill gas	5.94	7.58	6.78
Methane avoidance	11.34	4.25	3.73
N2O	1.45	8.95	8.44
PFCs and SF6	0.30	0.46	0.54
Reforestation	0.95	0.49	0.81
Solar	0.78	0.08	0.10
Tidal	0.02	0.04	0.05
Transport	0.26	0.18	0.18
Wind	16.56	10.00	10.75

Source: Based on UNEP Risoe CDM/JI Pipeline Analysis and Database, September 01, 2009.

Table 3. Estimates of the Potential Demand for Emissions Reductions and Size of the CDM Market by 2010.

Study	Annex B Countries' Demand for Kyoto Units under the Protocol mtCO$_2$e/year	Potential Size of the CDM Market mtCO$_2$e/year
Blanchard, Criqui, and Kitous [a] (2002)	688−862	0−174
Eyckmans et al. [a] (2001)	1,414−1,713	261−499
Grutter [a] (2001)	1,000−1,500	0−500
Haites[b] (2004)	600−1,150	50−500
Halsnæs[b] (2002)	600−1,300	400-520
Holtsmark[b] (2003)	1,246−1,404	0−379
Jotjo and Michaelowa [a] (2002)	1,040	0−465
Van der Mensbrugghe (1998)	1,298	397
Vrolijk[b] (2000)	640−1,484	300−500
Zhang[b] (1999)	621	132−358
Range	600−1,713	0−520

Note: [a]The forecasts assume that only the United States does not ratify the Kyoto Protocol; [b]the forecasts assume that Australia and the United States do not ratify the Kyoto Protocol. Sources: Haites (2004) and Zhang (1999).

Table 4: Selected Sample Summary Statistics

Project start	Number of projects	New CERS mtCO2e 2008-2012	New CERS mtCO2e 2008-2020	Stock of CERs mtCO2e 2008-2012	Stock of CERs mtCO2e 2008-2020	Withdrawn CERs Share of 2012 stock
2003 (1 month)	4	9.08	8.92	9.08	8.92	-
2004	48	7.91	7.14	16.98	16.05	0.028
2005	441	120.70	120.86	137.68	136.92	0.025
2006	664	131.93	159.62	269.61	296.55	0.067
2007	1165	124.50	171.34	394.11	467.88	0.132
2008	1464	111.55	174.55	505.66	642.43	0.139
2009 (9 months)	845	51.70	99.22	557.36	741.64	0.122

Source: UNEP Risoe (2009) and authors' calculations.

Table 5: Estimation Results

	2008-2012		2008-2020	
	Estimate	Std. error	Estimate	Std. error
	Symmetric 3-parameter model			
m	575.414^{a}	7.002	799.071^{a}	14.280
b_0	-3.638^{a}	0.089	-3.852^{a}	0.090
b_1	0.003^{a}	0.0001	0.003^{a}	0.0001
	Asymmetric 4-parameter model			
m	694.776^{a}	21.338	1,078.38^{a}	48.620
b_0	-20.705^{b}	9.178	-29.608^{b}	12.334
b_1	0.002^{a}	0.00007	0.001^{a}	0.00007
b_2	17,104.28^{a}	5.430	17,330.63	11.856

Superscripts ^{a} and ^{b} indicate significance at the one and five percent level, respectively. The standard errors were adjusted to take into account monthly variations in the number of projects entering the CDM baseline.

Table 6: Related inference tests

Dependent variable	CERs to 2012	CERs to 2020
Model	Steady-state flows (mtCO$_2$e)	
Symmetric	575	799
Asymmetric	694	1,078
Tests of symmetric and asymmetric models		
Upper bounds are equivalent	F(1,23)=31.29[a]	F(1,23)=33.00[a]
Models are equivalent	$\chi^2(1)=1{,}296$[a]	$\chi^2(1)=1{,}323$[a]
Dependent variable	CERs to 2012	
Model	Symmetric	Asymmetric
Probability that cumulative CERs in August 2009 exceed 520 mtCO$_2$e	>90%	>99%
Upper bound = 520 mtCO$_2$e	F(1,23)=62.64[a]	F(1,23)=67.09[a]

[a] Indicates statistical significance at the 1 percent level.

Figure 1: CERS from New Projects and Total CERs from all Projects in the Pipeline from December 2003 to August 2009.

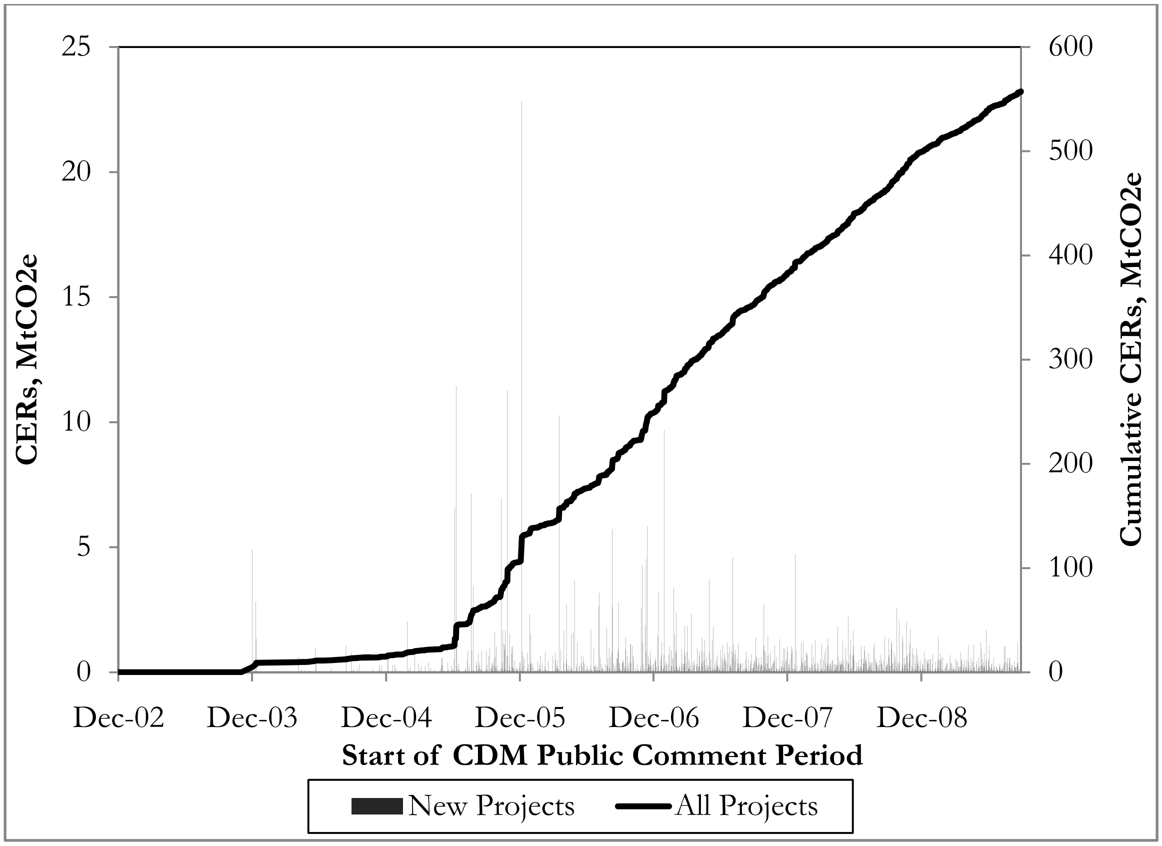

Figure 2: Actual and Predicted Annual 2008-2012 CERs

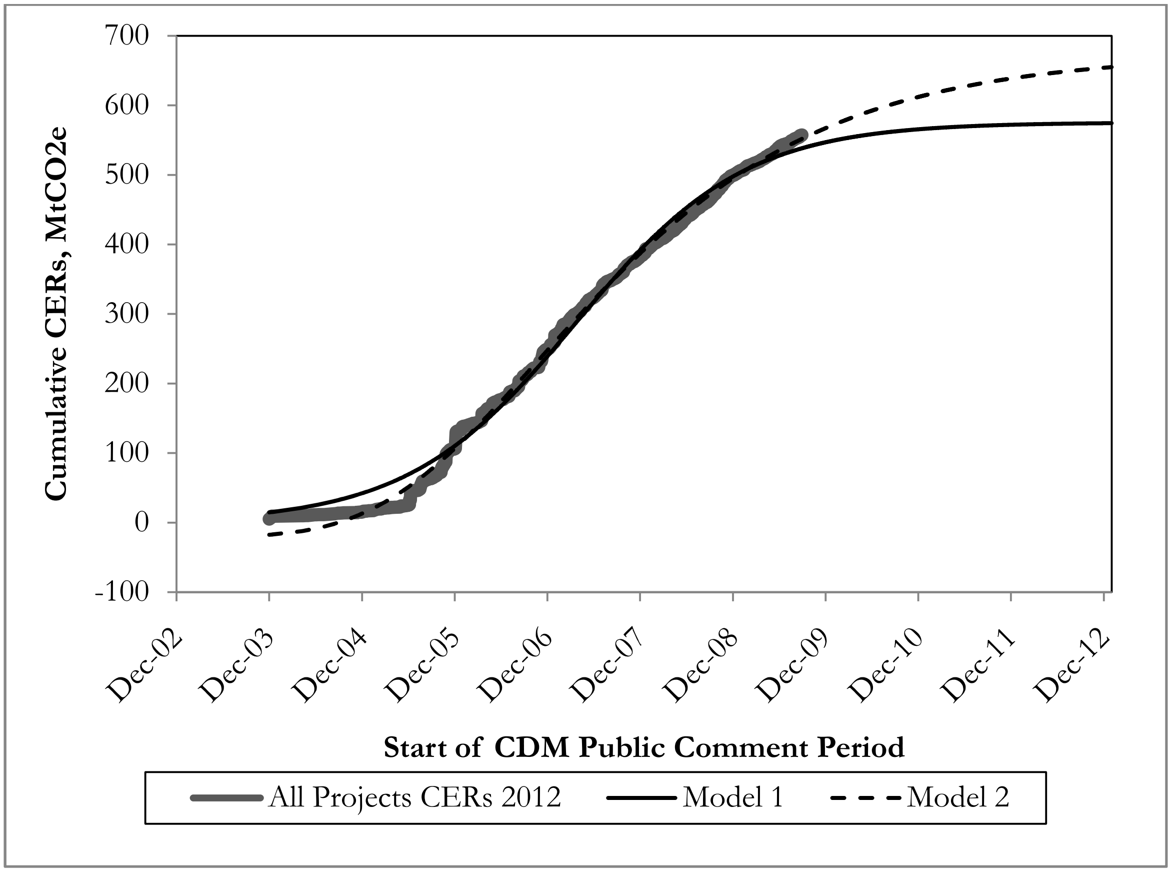

Figure 3: Actual and Predicted Annual 2008-2020 CERs